Fuzzy Modelling of Youth, Education and Skill Development in India

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ABSTRACT

In this present paper, the framework of youth empowerment, education and skill development are pivotal for socio-economic transformation in India. Currently traditional binary assessment techniques fail to adequately model the inherent uncertainties in human capabilities and socio-economic contexts. We propose in this paper a fuzzy logic-based modelling framework to systematically analyze youth development outcomes by integrating educational attainment, skill competencies, employability and socio-economic factors. This proposed model captures vagueness and subjective judgements using fuzzy sets and membership functions. Through empirical application on nationally representative data, fuzzy clusters reveal nuanced patterns of youth capability development across states. This paper contributes to policy modelling by providing a robust methodology to inform targeted interventions for education and skill development programmes.

Keywords: Fuzzy modeling, youth development, education, skill development, fuzzy sets, India, policy analysis.

INTRODUCTION

In 2026, India has around 36-37 crore youth 15 to 29 age group forming a major part of the workforce. Around 40% of young graguate face unemployment or underemployment, indicating a series gap between education and job opportunities. Youth constitute a substantial demographic segment in India, with over 65% of the population below 35 years of age (According to Government of India, 2021). Education and skill development are critical determinants of employability, social mobility, and economic growth. However, traditional models of youth assessment rely on rigid classifications (e.g., literate vs illiterate) that oversimplify complex human states. A major issue is that degree do not guarantee employment .Recent report show that 67% of unemployed youth are graduates, highlighting the mismatch between academic learning and industry needs. In reality, competencies such as critical thinking, problem-solving and vocational skills cannot be crisply categorized; they reside in gradations. Fuzzy logic, set fuzzy theory and its applications introduced [1, 2] offers a powerful tool for modelling such gradations and uncertainty.Fuzzy modelling allows representing subjective human judgments, partial membership in categories (e.g., “moderately skilled”, “highly educated”), and complex interdependencies among factors. Applying fuzzy systems to evaluate Indian youth’s educational and skill status can yield insights that conventional models obscure. Fuzzy logic in skill based learning developed [6,8,9,18]. Vocational training impact on youth employabilityby Chatterjee[17] in 2018. Skill development and youth employability in India by Gupta [15] in 2221. Fuzzy Models for Socio-Economic [3,14]. Fuzzy logic in education quality assessment [5,16]. Fuzzy analytic hierarchy process and student evaluation by Turksen [4] in 1919. Fuzzy models for policy analysis in developing economies developed by Patel,[19] in 2022.

The novelty of this work lies in

- Analyze of policy modelling various contractive conditions.
- Comparative analysis and implementation of fuzzy modelling of youth, education and skill development in India

This approach develop Chatterjea, Verma and Gupta uses the **Mamdani approach** within a comparative structures.

Preliminaries

Fuzzy set: Let X be a univerce of discourse and x is any particular element of X. Then the fuzzy set A defined on X is a collection of ordered pairs.

$A=\{X, \mu_A(x): x \in X\}$, where $\mu_A(x): x \in [0,1]$

Youth Development in India

India has one of the largest youth population in the world with nearly 370 million individual in the age group15-29 years. Appling a fuzzy logic framework to youth development in India is a sophisticated way to handle a reality that isn't just black and white . In traditional policy-making a young person might be labeled as Employed or Unemployed. Howerver, fuzzy logic allows us to account for the gray areas –like underemployment, skill mismatches or varying levels of social empowerment.

Education as a Fuzzy Variable

Education attainment in India ranges from basic literacy to advanced professional degrees.In classical a binary or discrete variable,Qualified/Not Qualified, Pass/Fail,Qualified/Not Quaiified, Educated/Uneducated, such rigid classification ignores the complexity of human learning. Astudent who scores 59 percent is labeled fail, while one with 60 percent is pass,eventhough their knowledge levels may be nearly identical . This imitation highlights the need for a more flexibal model. A fuzzy approach considers that education is not an absolute state but a gradualprocess, where individuals possess knowledge to varying degrees. Thus education can be modeled as a fuzzy variable defined on a spectrum of learning levels.Education cannot be confined within rigid numerical boundaries. It is inherently continuous dynamic and context-depenndent.Modelling education as a fuzzy variable providesa more accurate and human frame work for understanding learning .This approach bridge the gap between quantative measurement and qualitative growth,making education systems more adaptive inclusive and meaningful.

Skill Development Under Fuzzy Framework

Skill development includes technical skill vocational training digital literacy,and soft skills and employment for Indian youth.Major scheme related to skill development program for youth.Skill Developpment is a multidimensional and dynamic process influenced by education, socio-economic background,adaptability and technological exposure.Traditional models often treat skilllevels as binary, which is unrealistic.A fuzzy framework rooted in fuzzy logic, allowsus to represent skill development in degrees capturing uncertainty and gradual improvement.

Present Scenario (Data Based)

- Only about 4 to 5% of Indian workforce has formal skill training
- Majority of workers are employed in the informal sector
- Urban areas have better access to training compared to rural areas(2015)
- Skill mismatch remains a major challenge in employment

Example of skill Development in India (Government policy)

- Mahatma Gandhi National Rural Emploment Guarantee Act
- Deen Dayal Upadhyay Gram Kaushal Yojana
- Deendyal Antyojana

- National Skill Development Corporation
- National Skill Development Agency
- Pradhan Mantri Kaushal Vikas Yojana
- Ministry of Labor and Employment
- Skill India Mission(2015)
- Entrepreneurship skills(2020)
- Soft and communication skills
- Technical and vocational skills

At present there are different ways of skills development project that has been very helpful program launched by Gol, just like

- Start Up India
- Digital India
- Digital and IT skills
- Make In India
- Stand Up India
- Ddu Kaushal Vikas Mission
- Har Hath Ko Kaam
- Seekho Aur Kamao
- Swarn Jayanti Gram Swarojgar Yojana, Etc.

Employment Assessment Using Fuzzy Logic

Employment assessment is a multidimrnsional process influenced by factors such as educational attainmpt,ckill proficiency, work experience and labour market demand. Conventional evaluation methods often classify individuals as either employable or unemployable which fails to capture the gradual and uncertain nature of real employment conditions. Fuzzy logic provides a more realistic framework by allowing partial membership across different employability categories. In a fuzzy logic–based model, employability is expressed through linguistic terms such as Low,Moderate and High .An individual may belong to more than one category simultaneously with varying degrees.For instance a youth with adequate academic qualification but limited practical skill may exhibit moderate employability rather than a definite status. By incorporating such intermediate states,fuzzy logic enables a nuanced assessement of employment potential. This approach supports evidence-based decision-making and helps design targeted skill development and workforce policies.

Year – wise Table

Year	Youth (Approx.)	Education	Skill Development	Employability
2015	34 crore	Enrolment increasing	Skill india launched	Low, skill gap high
2016	34.5,,	Expansion of higher education	Vocational schemes growing	Slight improvement
2017	35 ,,	Moderat equality issue	Formal training 2%	High Unemployment
2018	35.5	Enrolment high	Formal skill 4%	skill mismatch visible
2019	36,,	Digital education	Training programs	Moderate

		begins	expand	Employability
2020	36,,	Covid impact Learning loss	Skill programs slowed	Employment decrease
2021	36.2,,	Online learning growth digital	skill increased	Recovery phase
2022	36.5,,	NEP implementation Phase	Skill participation rising	Moderate improvement
2023	36.7,,	High enrolment	Training increased to 34% formal+informal	Emploabilty improving
2024	36.8,,	Quality still moderate	Formal training 4%	Gradual improvement
2025	36.9,,	Graduate unemployment Rising	1.6 croro trained	placement low
2026	37,,	access high, quality Moderate	Skill participation increasing	Employability 56%

LITERATURE REVIEW

Fuzzy Logic: Concepts and Applications

Fuzzy logic concept extends classical binary logic to handle imprecise information through fuzzy sets and membership degrees between 0 to 1 (Zadeh, In 1965). It has been applied in control systems (Ross, In 2010), decision support systems (Zimmermann, In 2001), and socio-economic modelling (Dymova & Nikulchev, In 2018).

Fuzzy Modelling in Human Capital Assessment

Studies have applied fuzzy logic to education quality evaluation (Kwan & Bal, In 2014), student performance assessment (Turksen,In 1999), and skill gap analysis (Haque et al.,In 2020). However, few have integrated fuzzy approaches to model youth development holistically in the Indian context.

Education and Skill Development in India

India's skill ecosystem includes formal education, vocational training through the Skill India Mission (In 2015) and industry partnerships (Ministry of Skill Development & Entrepreneurship, In 2020). However, challenges persist, including quality deficits, urban-rural disparities, and mismatch between skills and industry needs (Reddy & Mohan, In 2019).

Research Gap and Objectives

While existing research addresses facets of education or skills separately, there is a gap in integrated modelling that captures the interrelated and fuzzy nature of youth competencies. The objectives of this study are:

1. To conceptualize a fuzzy logic based model that integrates educational attainment, skill competencies, and employability likelihood.
2. To operationalize fuzzy sets for key youth development indicators in the Indian context.
3. To apply the model empirically on national survey data and interpret the fuzzy outcomes for policy implications.

METHODOLOGY

Research Design

This study follows a quantitative modelling approach enriched by fuzzy logic. It combines secondary datasets with fuzzy set theory to interpret multidimensional youth development states.

Data Sources

Data were sourced from:

- National Sample Survey (NSS) 75th Round on education and employment (2017–18).
- Periodic Labour Force Survey (PLFS) 2019–2020.
- Unified District Information System for Education (UDISE).

These datasets provide indicators on educational levels, skill training participation, employment status and socio-economic attributes.

Fuzzy Variables and Membership Functions

The model includes the following fuzzy input variables:

1. **Educational Attainment (Edu Attain)**: measured by years of schooling and diplomas.
2. **Skill Competency (Skill Comp)**: vocational training duration and assessment scores.
3. **Employability Index (EmpIdx)**: based on skill relevance and labour force participation.

Membership functions were defined using expert consultation and standard fuzzy shapes (triangular and trapezoidal functions). Linguistic terms and membership functions include:

- **Edu Attain:** Low, Medium, High.
- **Skill Comp:** Weak, Moderate, Strong.
- **EmpIdx:** Unlikely, Possible, Likely.

We have all membership functions map the variables to the [0,1] interval.

Fuzzy Rule Base

A rule base was constructed to express domain knowledge:

- **Rule 1**: IF Edu Attain is High AND Skill Comp is Strong THEN Emp Idx is Likely.

- **Rule 2**: IF Edu Attain is Medium AND Skill Comp is Moderate THEN Emp Idx is Possible.
- **Rule 3**: IF Edu Attain is Low OR Skill Comp is Weak THEN EmpIdx is Unlikely.

Other rules cover intermediate states to ensure full coverage of the input space.

Defuzzification

A centroid defuzzification method was used to convert fuzzy outcomes into crisp employability scores, enabling ranking and comparison across individuals and states.

Fuzzy Modelling Framework

The framework comprises three stages:

- **Fuzzification:** Converting crisp socio-economic and performance scores into fuzzy membership values.
- **Inference: A**pplying fuzzy if-then rules to compute fuzzy output sets.
- **Defuzzification**:Computing a crisp employability index for interpretation.

Mathematically, the fuzzy inference engine uses the **Mamdani approach** (Mamdani & Assilian, 1975), chosen for its interpretability in social contexts.

RESULTS

Fuzzy Membership Distributions

Across the national dataset, membership functions revealed:

- Large proportions of youth with medium EduAttain but weak Skill Comp, especially in rural regions.
- Higher membership degree in strong Skill Comp in urban clusters with vocational institutions.

Employability Outcomes

After defuzzification, the model produced the following insights:

- States with strong vocational ecosystems (e.g., Karnataka, Maharashtra) showed higher average employability scores.
- Regions with disparities between education quality and skill training (e.g., Bihar, Uttar Pradesh) exhibited lower employability despite moderate schooling.

Cluster Patterns

Fuzzy cluster analysis yielded three clusters:

1. **Cluster A – High Competence & High Employability**: Youth with strong education and skills.
2. **Cluster B – Moderate Competence & Potential Employability**: Youth with medium schooling and skill exposure.
3. **Cluster C – Low Competence & Low Employability**: Youth with weak skills despite schooling.

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These clusters have direct implications for region-specific policy targeting.

DISCUSSION

Interpretation of Findings

The results confirm that education alone does not guarantee employability; skill competencies play a significant role. Fuzzy modelling captures the fuzzy transition between “employable” and “unemployable,” unlike binary classifications from a fuzzy perspective the education system shows high coverage but only moderate effectiveness due to quality variation, skill development exhibits strong employability impact but limited reach. Youth development outcomes lie betweenthese systems, influenced by partial achievement in both education and skills.

Policy Implications

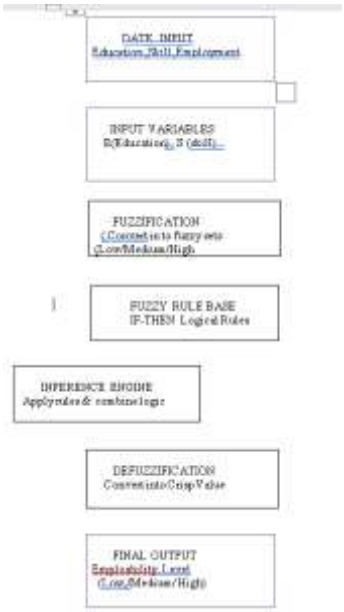
- **Customized Skill Interventions:** Regions dominated by Cluster C require targeted programs that build practical competencies rather than generic certification.
- **Curriculum Realignment:** Integration of industry-aligned skills in school and higher education.
- **Dynamic Monitoring:** Fuzzy models allow ongoing assessment of program effectiveness by tracking shifts in membership degrees over time.

Limitations and Future Work

This study uses existing secondry data, which may not capture all dimensions of skill quality. Future research could:

- Subjectivityin defining membership functions.
- Include employer feedback to refine fuzzy rules.
- Extend the model to multi-stage fuzzy cognitive mapping.
- Integrate machine learning to automate membership function optimization.

Graph of Fuzzy Model



Comparative Analysis of Youth,Education and Skill Development

Traditional comparisons use fixed values but youth development involves uncertainty and gradual transitions. A fuzzy based approach represents education, skills and employability using linguistic variables such as Low, Moderate and High each with partial membership.This allows a more realistic comparison of youth outcomes in India.

Fuzzy Comparative Table

Dimension	**Youth Development**	**Ecucation System**	**Skill Development**
Learning Effectiveness	Moderate	Moderate	High
Degree of Coverage	High	Very High	Low to Moderate
Practical Skill Orientation	Law to Moderate	Low	High
Employability to Markete Needs	Moderate	Low	High
Regionaly Uniformity	Low	Moderate	Low
Outcome Certainty	Low	Moderate	Moderate to High

[B] Important IT Skills and Training Suggestion

Skill Area	Key Skills	Training Suggestion
Programming	Python, Java , C $^{++}$ Java Script	Regular coding practice Project based learning
Data Structures & Algorithms	Problem solving, logic building	Daily problem solving coding competitions
Database Management	SQL,data handing	Practical database labs, Real datasets
Web Development	HTML,CSS, Java Script Backend	Build live project website development practice
Cybersecurity	Network security encryption	Basic security labs awareness training
Cloud Computing	AWS, Azure, Google cloud	Certification courses hands-on labs
Data science &AI	Data analysis, machine learning	Use tools like python, real World datasets
Soft skills	Communication, teamwork	Group discussions, presentation

Analytical skills	Logical thinking Decision- making	Case Studies problem-based learning
Professional Skills	Time management adaptability	Time management, adaptability

Challenges

- Low quality of training programs
- Lack of industry linkage
- Limited awareness in rural areas

CONCLUSION

In this study fuzzy modelling offers a nuanced and adaptable methodology for analyzing youth development in India. By capturing uncertainties in education and skills, the proposed framework enhances insights into employability and policy effectiveness. The integration of fuzzy sets, rule-based inference and defuzzification yields a robust analytical tool that bridges quantitative rigor with real-world complexity.Fuzzy- based comparison highlights that no single system fully ensures employability. Education and skill development contribute in varying degrees and their integration is essential for maximizing youth potential in India.This approach is especially relevant in modern education systems, workforce analytics and national development programs.

Conflicts of interest

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